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Report No. 4560372

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PRELIMINARY ANALYSIS OF ACODAC MEASUREMENTS NEAR MADEIRA ON 13-16 OCTOBER 1971 (U)

prepared for

THE OFFICE OF NAVAL RESEARCH
LONG-RANGE ACOUSTIC PROPAGATION PROJECT
CODE 102-OS

DDC FILE COPY

by

ARTHUR D. LITTLE, INC.
CAMBRIDGE, MASSACHUSETTS 02140

under

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5 May 1972

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10 Donald L./Luitinen,
Robert M./Kennedy
Emma M./Duchane

prepared for

THE OFFICE OF NAVAL RESEARCH
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ARLINGTON, VA. 22217

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TABLE OF CONTENTS

PRELIMINARY ANALYSIS OF
ACODAC MEASUREMENTS NEAR MADEIRA
ON 13 - 16 October 1971 (U)

I. INTRODUCTION (U)

(U) During the period 13 - 16 October 1971, two ACODAC arrays were deployed west-northwest of Madeira as a part of the ONR Long-Range Acoustic Propagation Program. The purpose of the deployment was to investigate a possible depth dependence in ambient noise and signals received from explosive charges. It was carried out under the direction of Dr. Roy Gaul, LRAPP Program Manager.

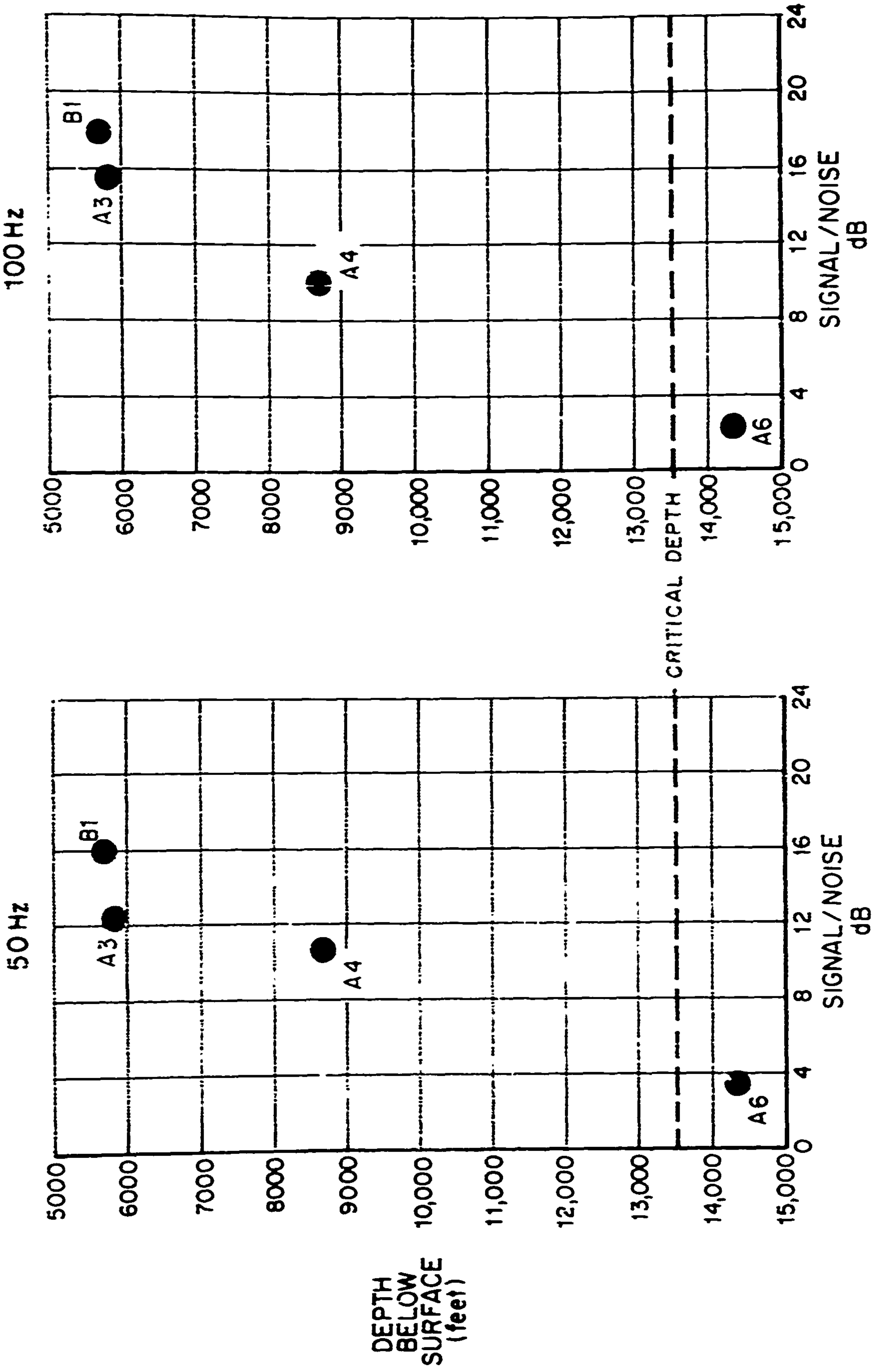
(U) This report summarizes a joint effort on the part of Arthur D. Little, Inc., and Woods Hole Oceanographic Institution. The ADL effort was directed by Robert Kennedy who was assisted by Emma Duchane, Donald Sullivan and Wendell Sykes. The WHOI effort was directed by Dr. Earl Hayes who was assisted by Constantine Tollias and David Bitterman. Dr. Sam Marshall of NRL and Dr. Scott Daubin of the University of Miami provided valuable assistance.

(C) The task reported here was begun in late December 1971. Its purpose was to make a preliminary estimate of the degree of depth dependence in the ratio of shot signal amplitude to ambient noise observed during the Madeira deployment.

II. EXECUTIVE SUMMARY (U)

(C) During the period 13 - 16 October 1971, two ACODAC arrays were deployed 130 NM WNW of Madeira for the observation of depth dependence in acoustic signal-to-noise ratio using explosive charges as a signal source at a depth of 300 feet and distances of 5 to 280 NM. Bottom depth at the array locations is approximately 15,000 feet.

(C) Despite difficulties with the instrumentation, enough valid data was obtained to demonstrate conclusively a significant decrease in signal-to-noise ratio with depth. This depth dependence is shown in the following Figure 13 for the 1/3 octave bands at 50 and 100 Hz.



PEAK SHOT SIGNAL TO HOURLY AVERAGE AMBIENT NOISE RATIO VS DEPTH (U)

22-2400 Z

15 OCT. '72

FIGURE 13

III. DESCRIPTION OF MEASUREMENTS (U)

A. ACODAC (U)

(S) During 13 - 16 October 1971, two ACODAC arrays were deployed WNW of Madeira for the observation of a possible depth dependence in the acoustic signal-to-noise ratio using explosive changes as a signal source. The test area is shown in Figure 1 and the test geography in Figure 2. The two arrays were moored at locations A and B approximately 10 NM apart. The RV KNORR was anchored about 45 NM SE of the ACODAC arrays and the RV GIBBS was anchored about 280 NM NW of the arrays. The RV MIZAR followed the track shown in Figure 2 starting at 2350/14 October and ending at 0528/16 October. The test consisted of three events. During event 99 a group of charges was set off at 18" depth as the MIZAR steamed SE. No signals were received by the ACODAC arrays from these shots. During event 100 the MIZAR steamed NW from the KNORR at 12 knots, dropping 2 lb. explosive charges every 2 1/2 minutes, set to explode at a depth of 300'. During event 101 another group of charges was detonated at 18" depth and again no signals were received. Further details of this test can be found in the "Eastlant Operation Plan," 31 August 1971, by Dr. Scott Daubin (Chief Scientist), University of Miami.

(U) A typical ACODAC array configuration is shown in Figure 3. The system is capable of operating independently of the surface. The signals from six hydrophones can be recorded either continuously or periodically on magnetic tape. Total recording time can be up to seven days at 15/160 IPS. The array and instrumentation may be recovered by an acoustic command or by a time release.

(U) The vertical disposition of hydrophones for which data was analyzed is shown in Figure 4, superimposed on a velocity profile measured at the KNORR location on 17 October.

(U) Data from hydrophones A1, A2, B3 and B5 were not analyzed at this time, since the quality appeared to be low, and adequate depth coverage was obtained from the other hydrophones. We plan to look more closely at data from these hydrophones at a later date.

(U) The depth of the KNORR's two anchor hydrophones is also shown in Figure 4. Note that the KNORR is approximately 40 miles from the two ACODACS.

(C) The A array recorded continuously at 15/160 IPS in the 20-300 Hz band from 1700/13 October to 2200/16 October and the B array recorded continuously at 15/16 IPS in the 20-3000 Hz band from 1936/15 October to 2116/16 October. Both arrays had three levels of automatic gain switching, in 27DB steps and included internal calibration signals at 12-hour intervals.

(U) The data recording and playback system block diagram is shown in Figure 5. An important feature of the system is the automatic gain switching circuit which changes the gain in 27 DB steps in response to one minute averages of the recorder input. The overload detector is independent of the gain switching circuit. Since the overload detector bandwidth is about 6 KHz, it responds very rapidly and thus prevents blocking of the electronics by severe overloads. When an overload is detected the preamplifier output is disconnected and a 200 Hz sine wave is injected into the recorder as an easily identifiable marker.

B. RELATED MEASUREMENTS (U)

(S) At the time of the ACODAC recordings, the KNORR and the GIBBS both had deployed Anchor Hydrophones as a part of the NEAT II operation. The Anchor Hydrophone actually consists of a pair of hydrophones, one on the bottom and the other 500 feet above the bottom. The GIBBS noise data are not included here because of its distance from the ACODAC arrays but some ambient noise data taken by the nearby KNORR have been made available by R. Nowak of WHOI for comparison with the ACODAC data.

IV. ANALYSIS (U)

A. GENERAL (U)

(U) The analysis for this task consisted of playback of the raw data through 1/3 octave filters into an 8-channel chart recorder, followed by manual editing to reject invalid data. The valid data was then visually averaged over time intervals typically on the order of an hour to obtain ambient noise levels. Peak amplitudes of shot signals were also read directly from the chart.

B. DESCRIPTION OF DATA (U)

(U) A typical section of data is shown in Figure 6. The 50 DB span of the chart record is established in the playback process. The calibration pulse is injected at the hydrophone preamlifier output every 12 hours and is equivalent to sound pressure levels of + 34.5, + 7.5 and - 19.5 DB//μbar, depending on the setting of the automatic gain switch. The primary cause for rejection of data is also shown in Figure 6 in the vicinity of 2200 where the overload detector has operated before the gain switching amplifier has had a chance to respond. Since the three gain states were not overlapping, it was possible for the average value of the data to be low enough not to cause a gain state change, yet high enough that peak excursions of the data were consistently in overload. Such sections of data were edited out.

(U) Corrections were applied to the data from all hydrophones to account for cable attenuation of 0.18 DB/1000 ft., the maximum correction being 1.6 DB for hydrophone A6. In addition, a 3 DB correction was applied to all data from the B hydrophones to compensate for the difference in system response between the 500 Hz calibration signal frequency and the 50 and 100 Hz data frequencies. Finally, the shot amplitudes from hydrophone B1 were reduced by 2.5 DB to account for certain differences in playback system response that originated in the 10:1 difference in recording speeds between the A and B arrays.

C. ESTIMATE OF ERRORS (U)

(U) Ambient noise averages were obtained by adjusting a transparent straight edge over the data until it looked right to the eye. Reproducibility of this estimate from trial to trial and individual to individual is well within ± 1 DB. Peak values of shot signals were readable to ± 0.5 DB. Hydrophone plus preamplifier sensitivity was established by the N.R.L. calibration facility at Orlando with an accuracy of ± 0.5 DB. The variation in sensitivity among the hydrophones is on the order of ± 0.5 DB. The calibration pulse amplitude is known with an accuracy of about ± 0.5 DB. Since calibration pulses are not always at the frequency of interest, the system frequency response was measured with an accuracy of ± 0.5 DB. The "linearity" of the logarithmic amplifier is about ± 1 DB. Finally, the 50 DB span of the chart record is adjusted at the beginning of each record within ± 0.5 DB.

(U) There is also an uncertainty of about ± 2 DB that is manifested as an apparent change in signal level during automatic gain switching. The signal level does not change by exactly 27 DB when the gain switches. No explanation has been found for this discrepancy.

(U) If these errors are assumed statistically independent, the RMS uncertainty in absolute sound pressure levels for the combined errors will be approximately ± 2.8 DB.

V. CONCLUSIONS (U)

A. AMBIENT NOISE (U)

(S) Time histories of the ambient noise in the 50 and 100 Hz 1/3 octave bands are shown in Figures 7 and 8. The plotted points are average values of noise during the hour preceding the point and represent essentially all of the valid data. Gaps in the data are due to system overloads. Also shown, for comparison, is the ambient noise seen by an Anchor Hydrophone 500 feet above the bottom at the KNORR, 45 NM SE of the ACODAC arrays.

(U) Figure 9 illustrates the depth dependence of ambient noise for a group of 15 half-hour intervals during the 24-hour period when the A and B moorings were recording simultaneously. The 15 intervals were selected on the basis that at least seven of the eight hydrophone channels were delivering valid data. In this way we avoid biasing the results through exclusion of data that may be in overload because it is loud. The interval associated with each data point is the standard deviation calculated for the 15 time intervals.

B. DEPTH DEPENDENCE OF SIGNAL-TO-NOISE RATIO (U)

(U) During event 100 the peak amplitudes of the shot signals were recorded and are plotted in Figures 10 and 11 together with the one-hour average values of ambient noise. Because of overloads, valid shot data exists for only four hydrophones and then only when the MIZAR was about 100 miles downrange from the ACODACS.

(U) Peak amplitudes were recorded for the shot signals, rather than the usual total energy, because the effect being investigated is the change in signal-to-noise ratio versus depth, rather than the absolute signal-to-noise ratio for a given source level as seen through the propagation loss. Figure 12 shows the actual shot signals and noise at various depths. In spite of the limited amount of data, the variation in signal-to-noise ratio with depth can be seen quite clearly.

(U) Figure 13 summarizes the depth dependence of signal-to-noise ratio for the period 2200-2400/15 October, when both signals and noise are available for all four hydrophones simultaneously. Note that the quantity plotted is the average value of the peak shot signal amplitudes for the two-hour period, less the average value of noise for the same period, both values as measured in a 1/3 octave band. We believe that the high S/N ratio for hydrophone B1 is real, though not understood, because the noise level of B1 as seen in Figure 9 correlates well with the noise level seen by other nearby hydrophones.

C. COMPARISON WITH NEAT DATA (U)

(C) During the period 1400-2200/16 October, ambient noise data is available simultaneously from the KNORR's upper anchor hydrophone and the ACODAC A4 hydrophone, which is closest in depth. These data are compared in Figure 14 and show excellent agreement with the discrepancies attributable to the difference in hydrophone depth. Figure 15 compares the statistical distribution of the one-hour averages of ambient noise from ACODAC hydrophone A4 and the five-minute averages of ambient noise from the KNORR's upper anchor hydrophone. The ACODAC A4 distribution includes all of the A4 noise data from Figures 7 and 8 (62 hours from 2000/13 October to 2200/16 October), while the KNORR data includes all of the noise data from Figure 14 (25 hours from 1330/16 October to 1430/17 October).

(S) In addition, Figure 16 shows how the ACODAC data compares with other ambient noise data taken during the NEAT I and NEAT II exercises. The choice of 10° west longitude as an origin is somewhat arbitrary but invites speculation that dense north-south shipping off the Portuguese coast is an important source of ambient noise in the area. The smooth curves in the figure show how noise from such a source would be attenuated through spherical spreading.

D. CAUTION (U)

(U) Two cautionary statements concerning this analysis are appropriate. First, a narrow-band analysis to detect cable strumming is not yet complete. However, the agreement between the ACODAC and KNORR measurements, as summarized in Figures 14 and 15, implies that strumming is not likely to be a major problem. Second, the rejection of large portions of the data because of recording system overloads could be a source of bias. Again, Figure 15 shows no obvious difference in statistics between A4 which was in severe overload and the KNORR which was not. We feel, therefore, that the depth dependence of signal-to-noise ratio, as shown in Figure 13, is not due to artifacts induced by the instrumentation or the analysis process.

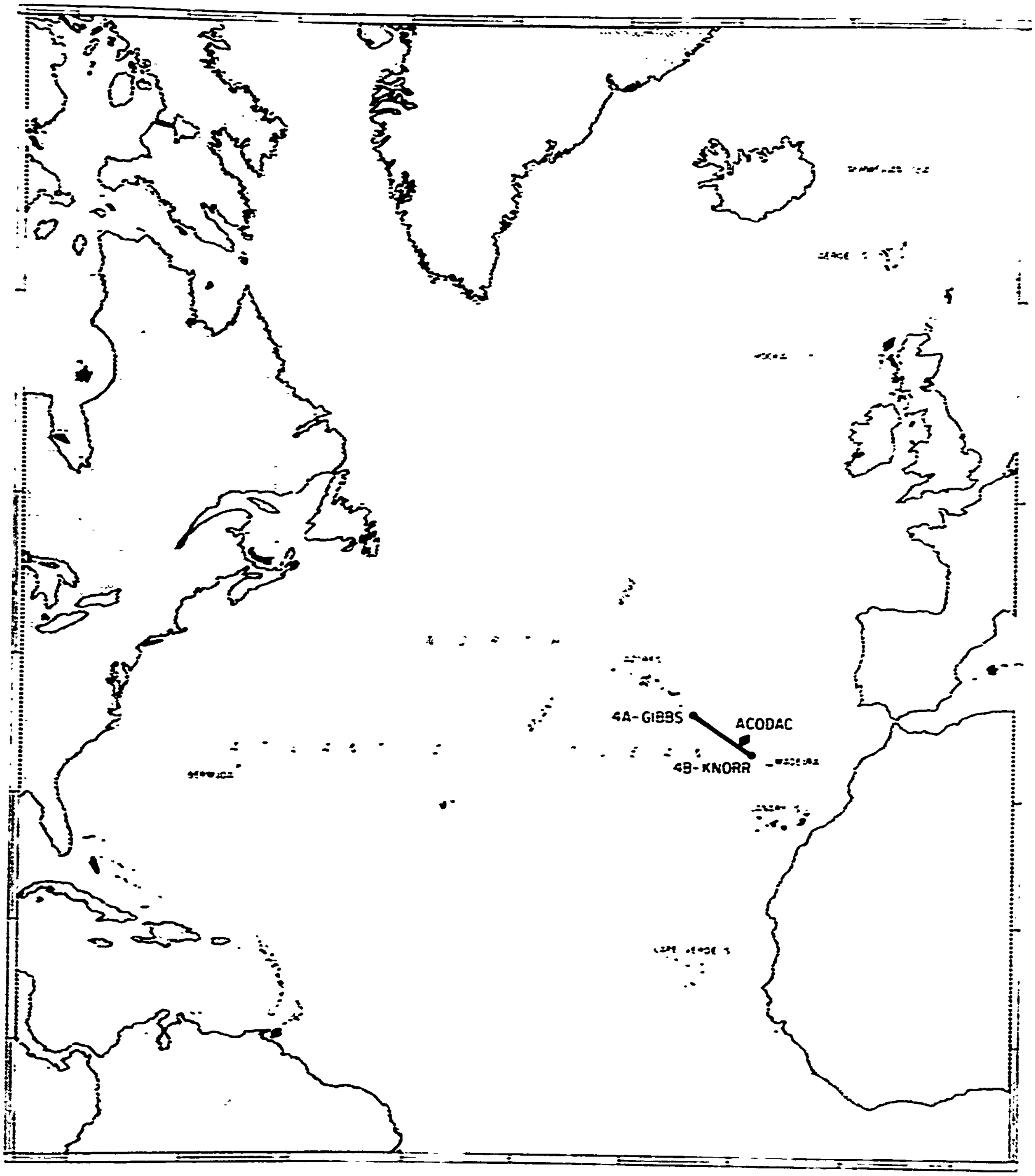


FIGURE 1

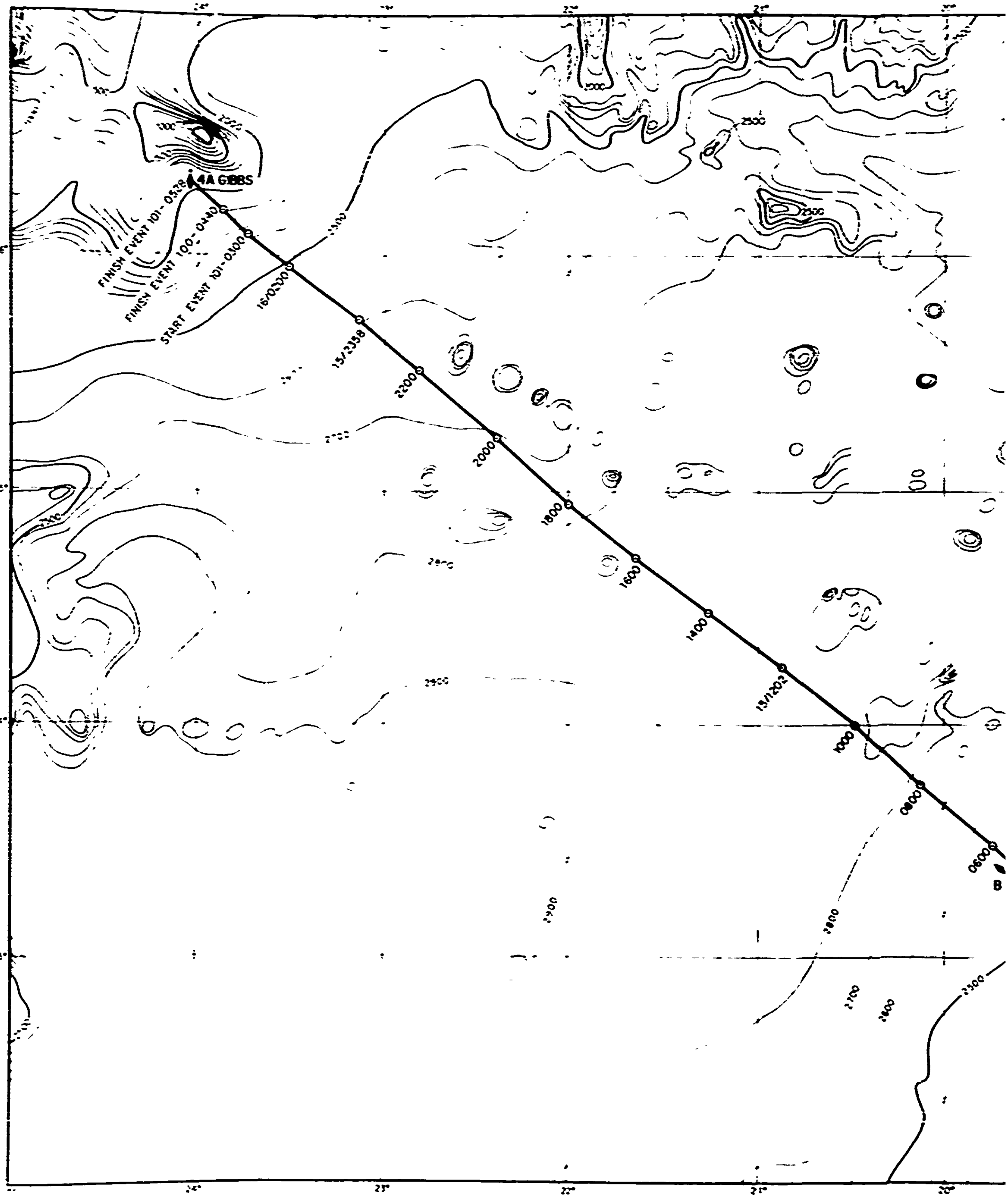


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FIGURE 2

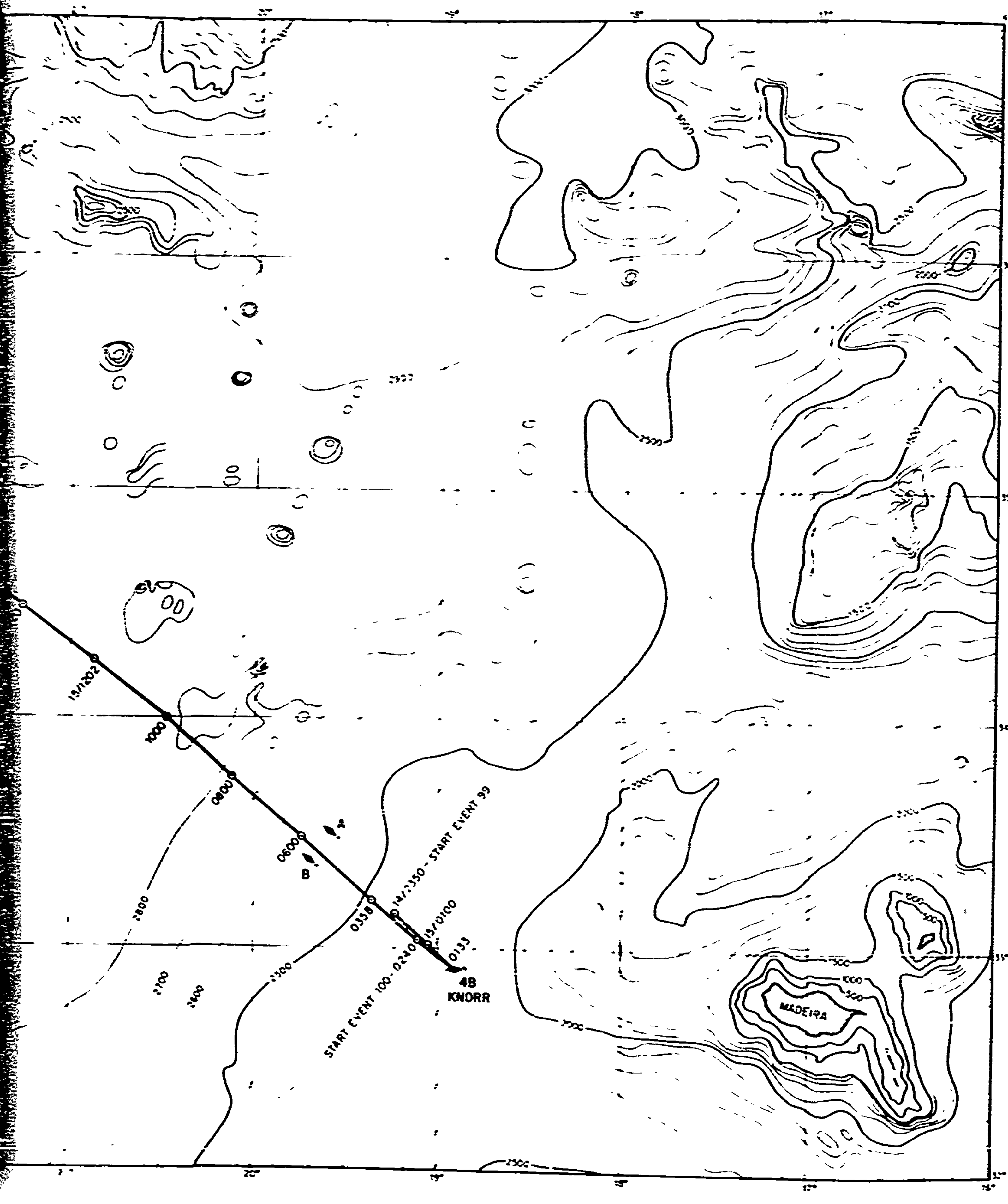
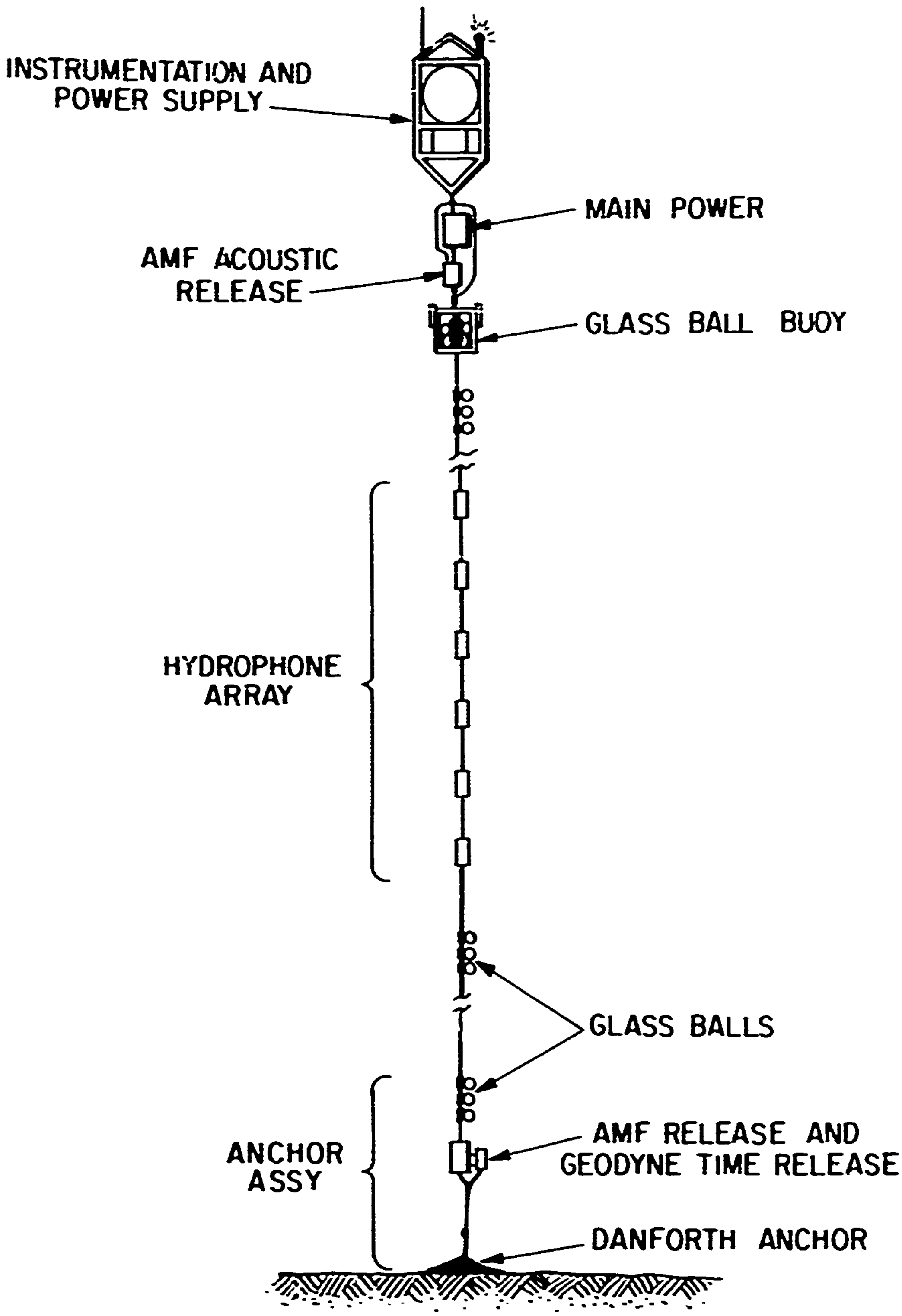
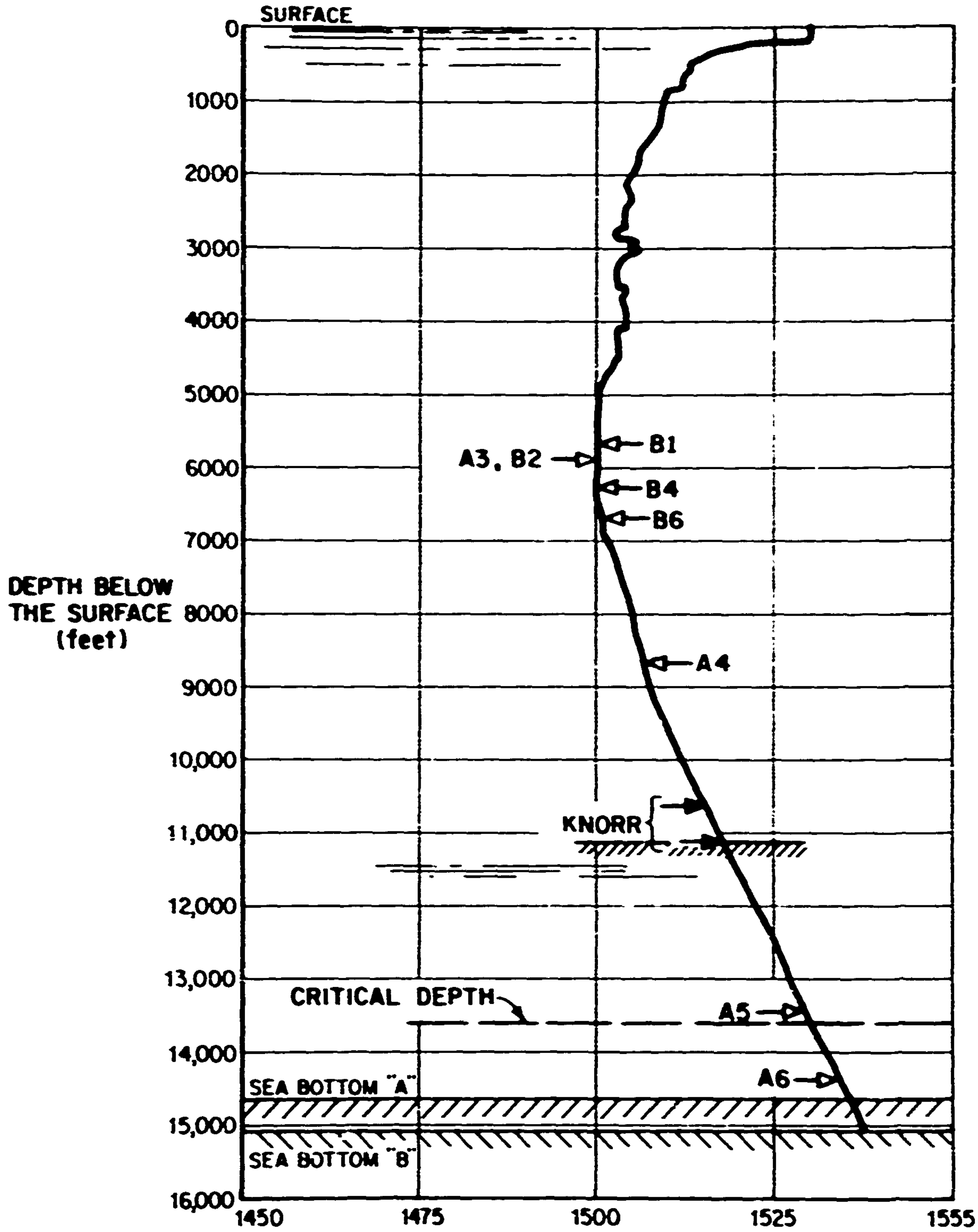

13/1202
1000
0800
0600
A
B
0358
14/2350 - START EVENT 99
15/0100
0240
0133
START EVENT 100
4B
KNORR
MADEIRA
2500
20°
19°
18°
17°
16°
35°
34°
33°
32°

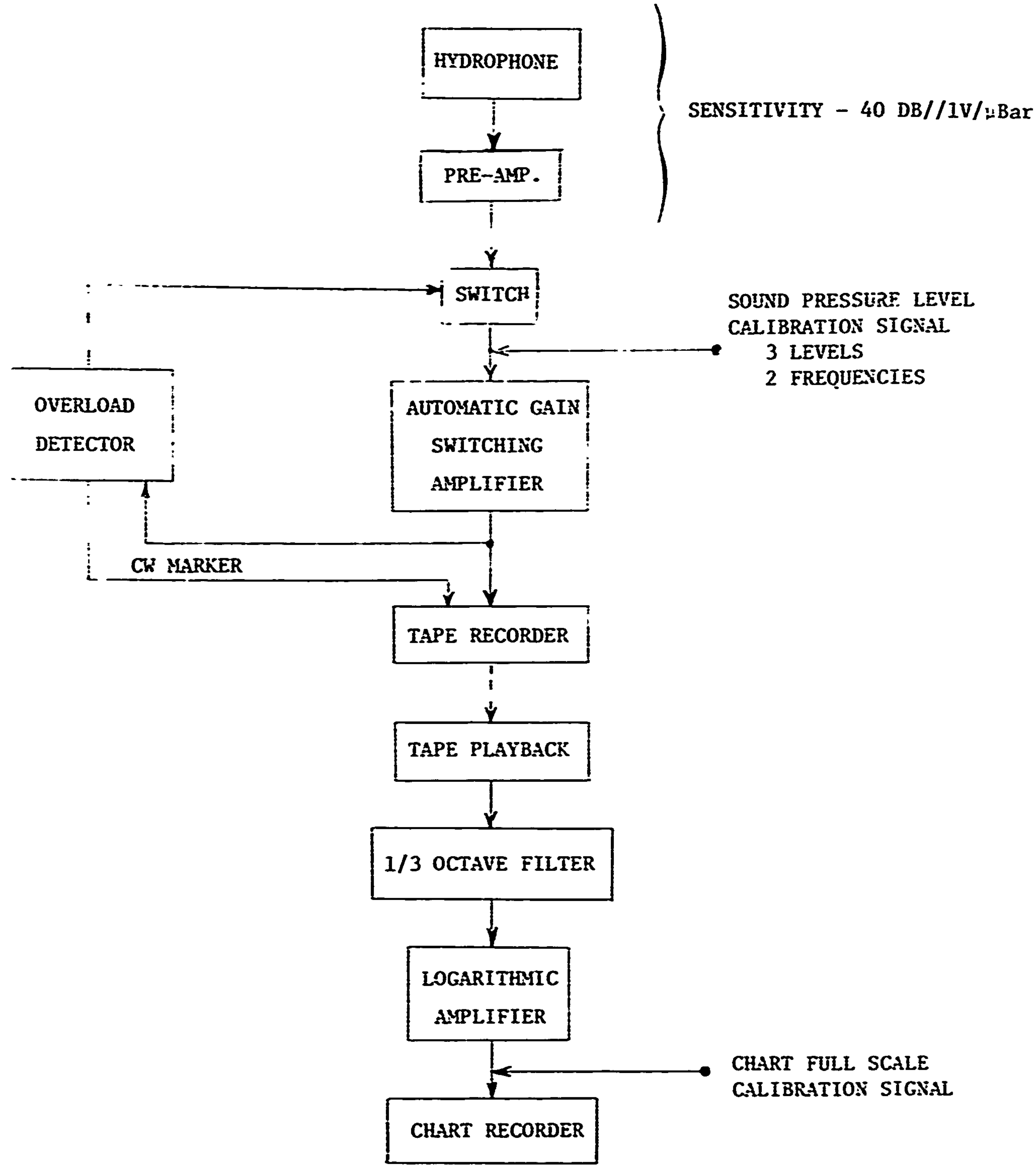
FIGURE 2



WOODS HOLE ACODAC ARRAY
TYPICAL CONFIGURATION (U)
FIGURE 3



MEASURED 45 NM SE OF ACODAC ARRAYS (U)
FIGURE 4



DATA RECORDING - PLAYBACK SYSTEM (U)

FIGURE 5

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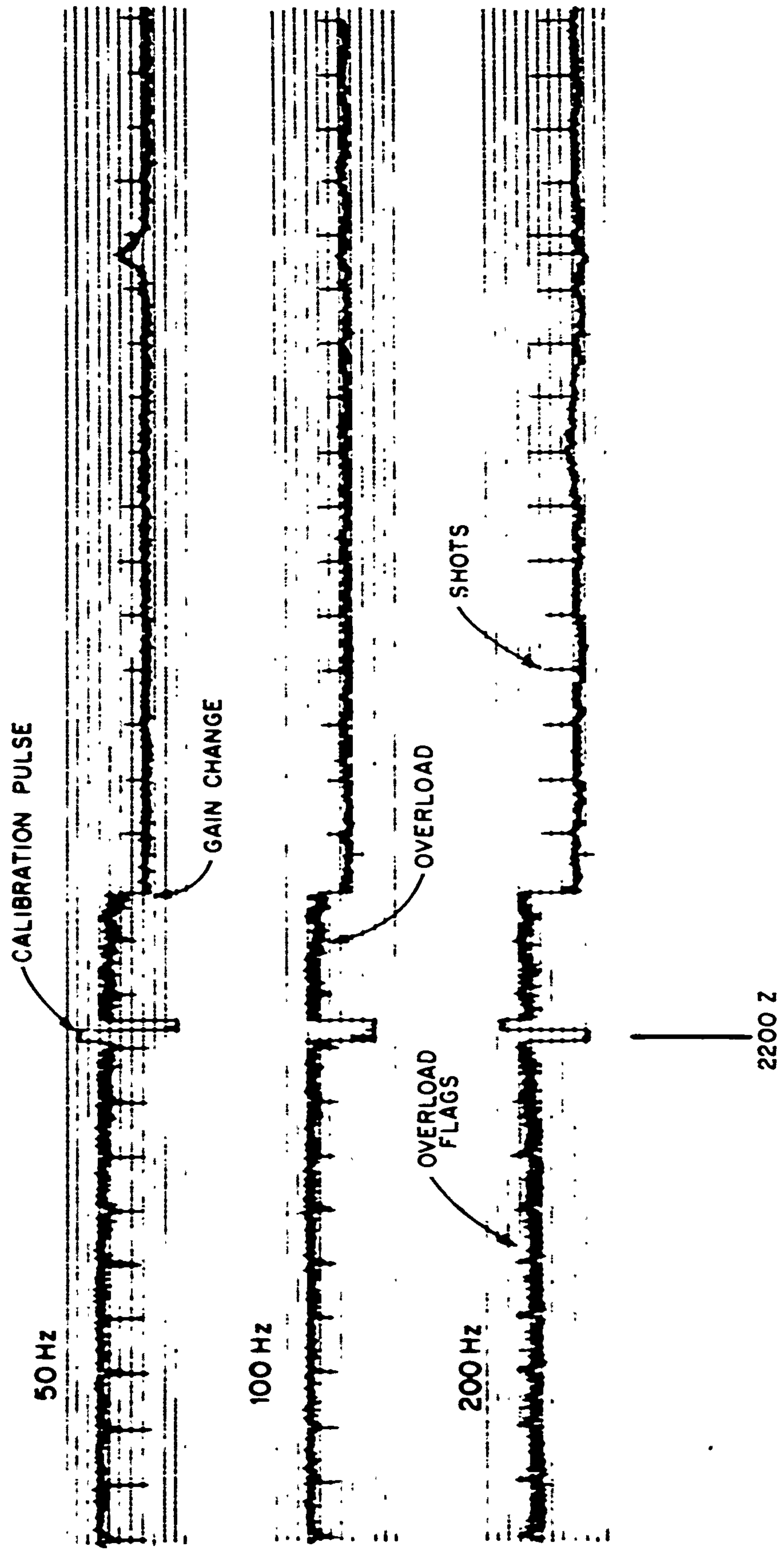

DATA EXAMPLE (U)
FIGURE 6

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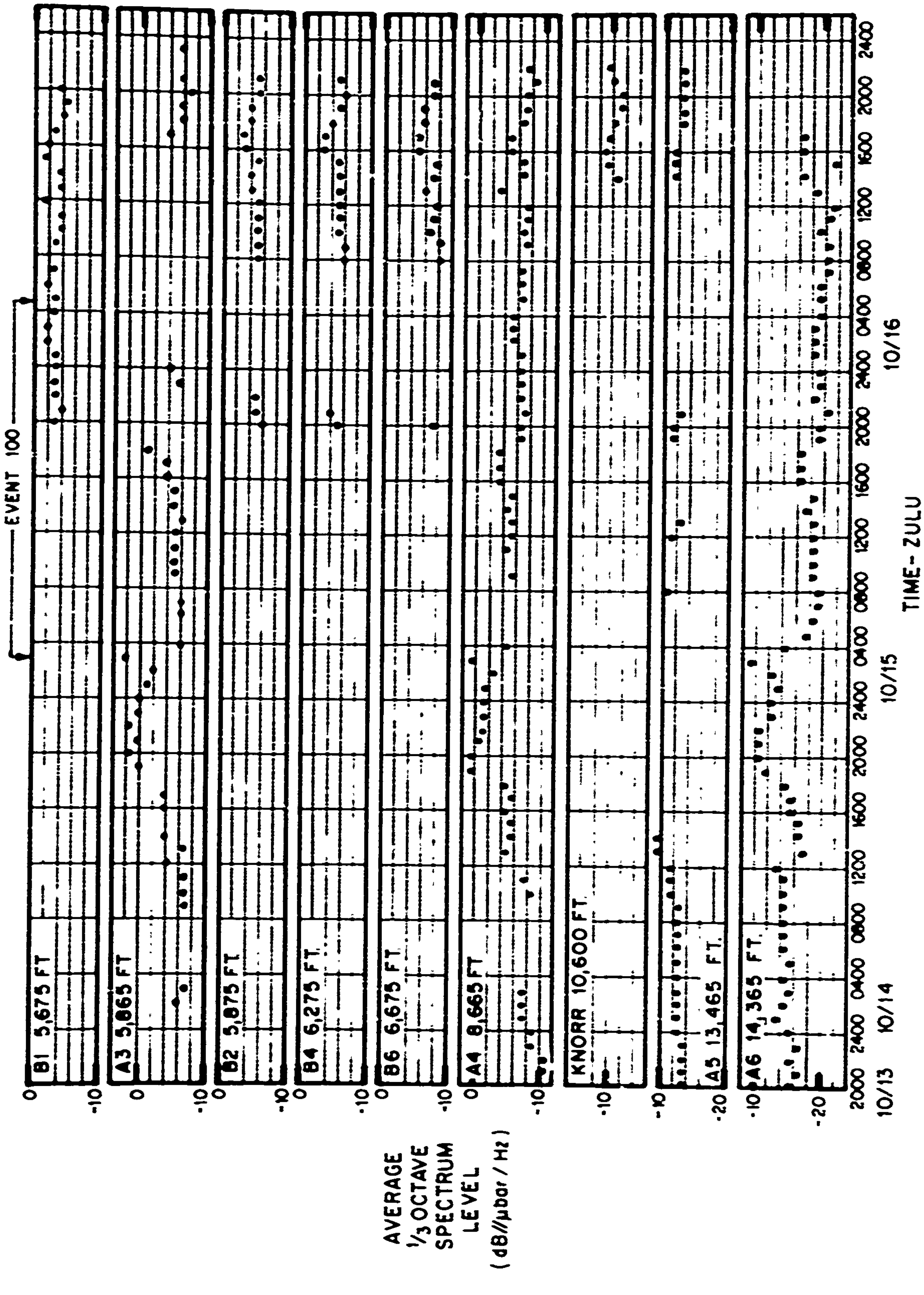
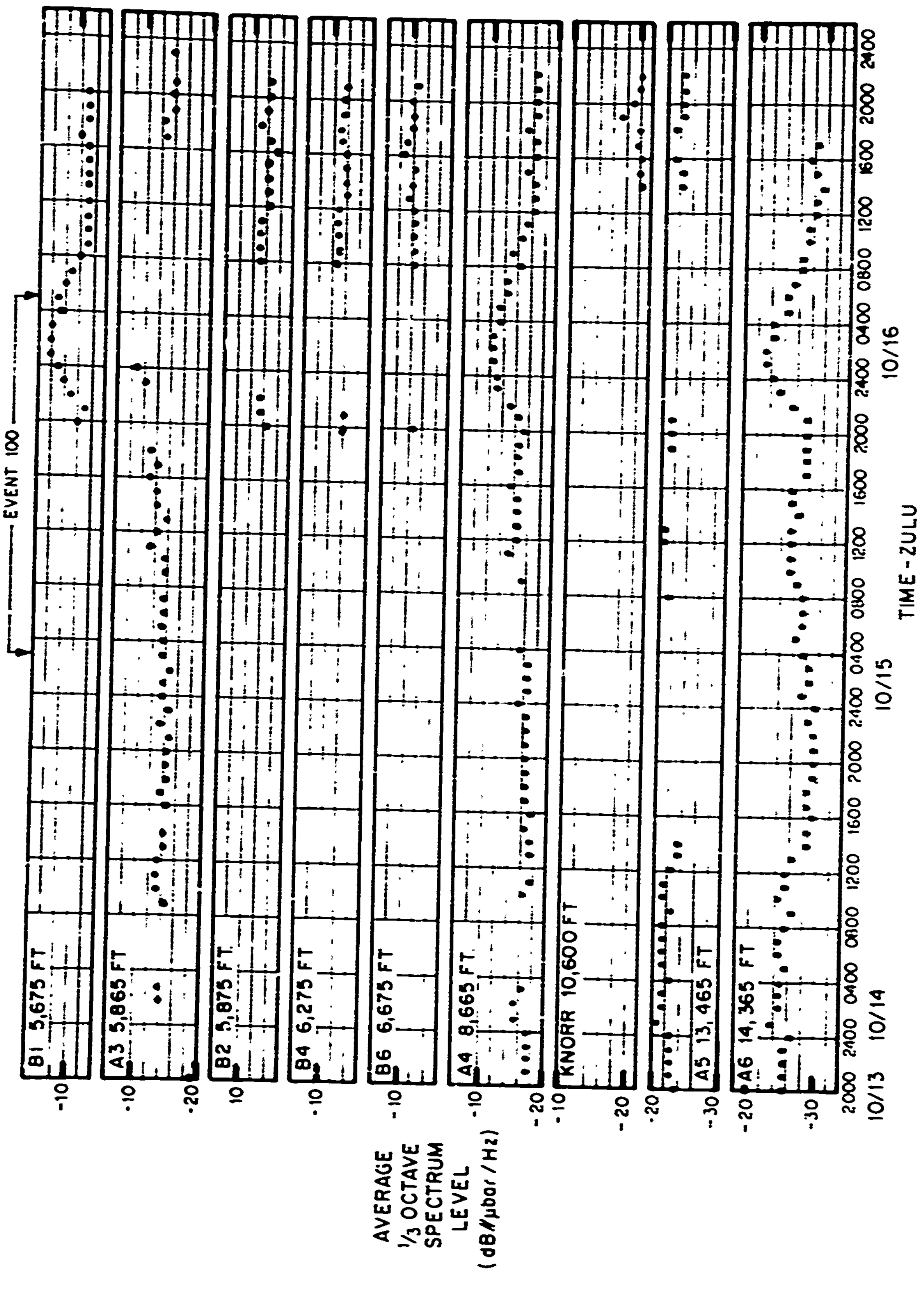
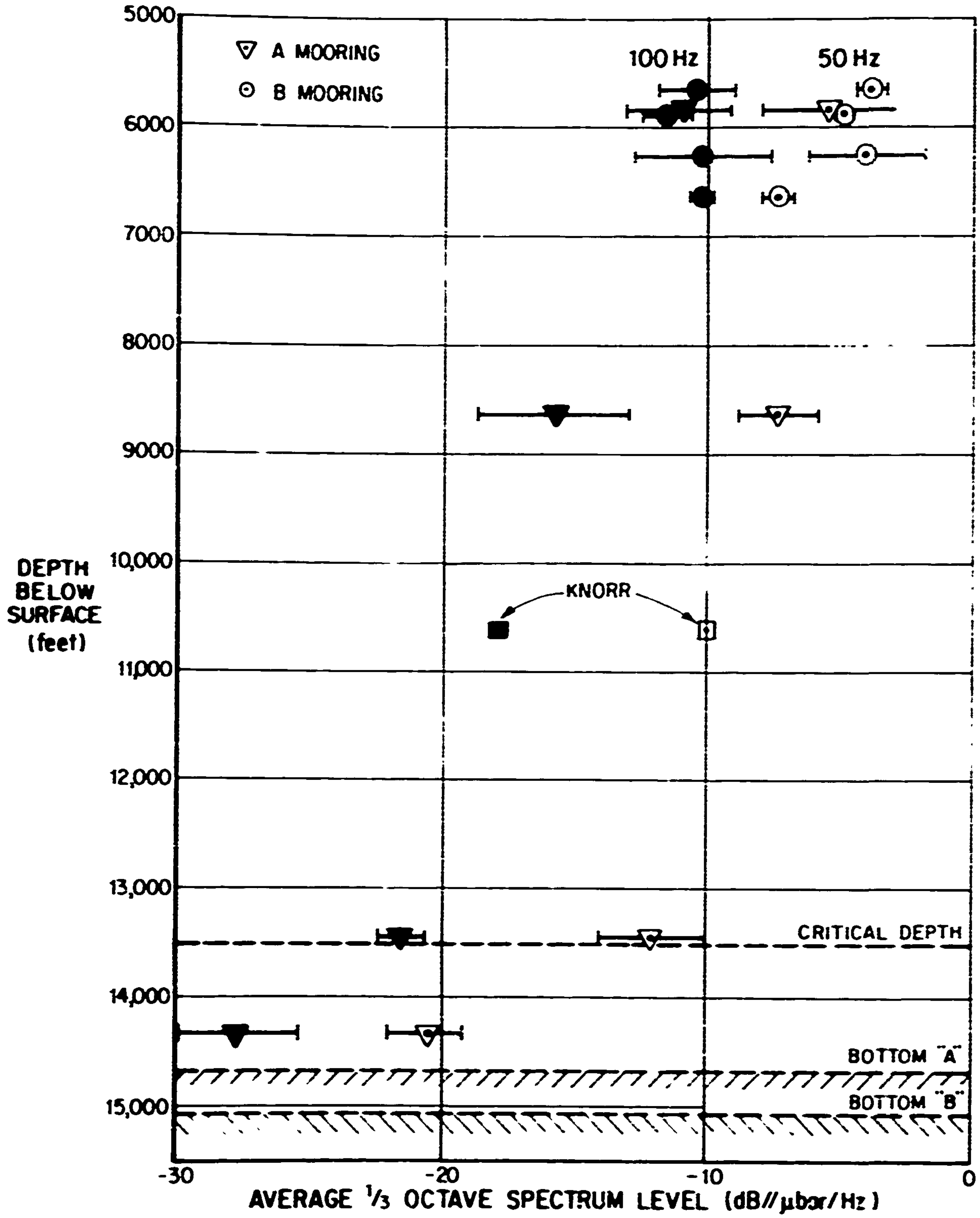


AMBIENT NOISE - ONE HOUR AVERAGES (U)
MEASURED IN 1/3 OCTAVE BAND AT 50Hz
FIGURE 7

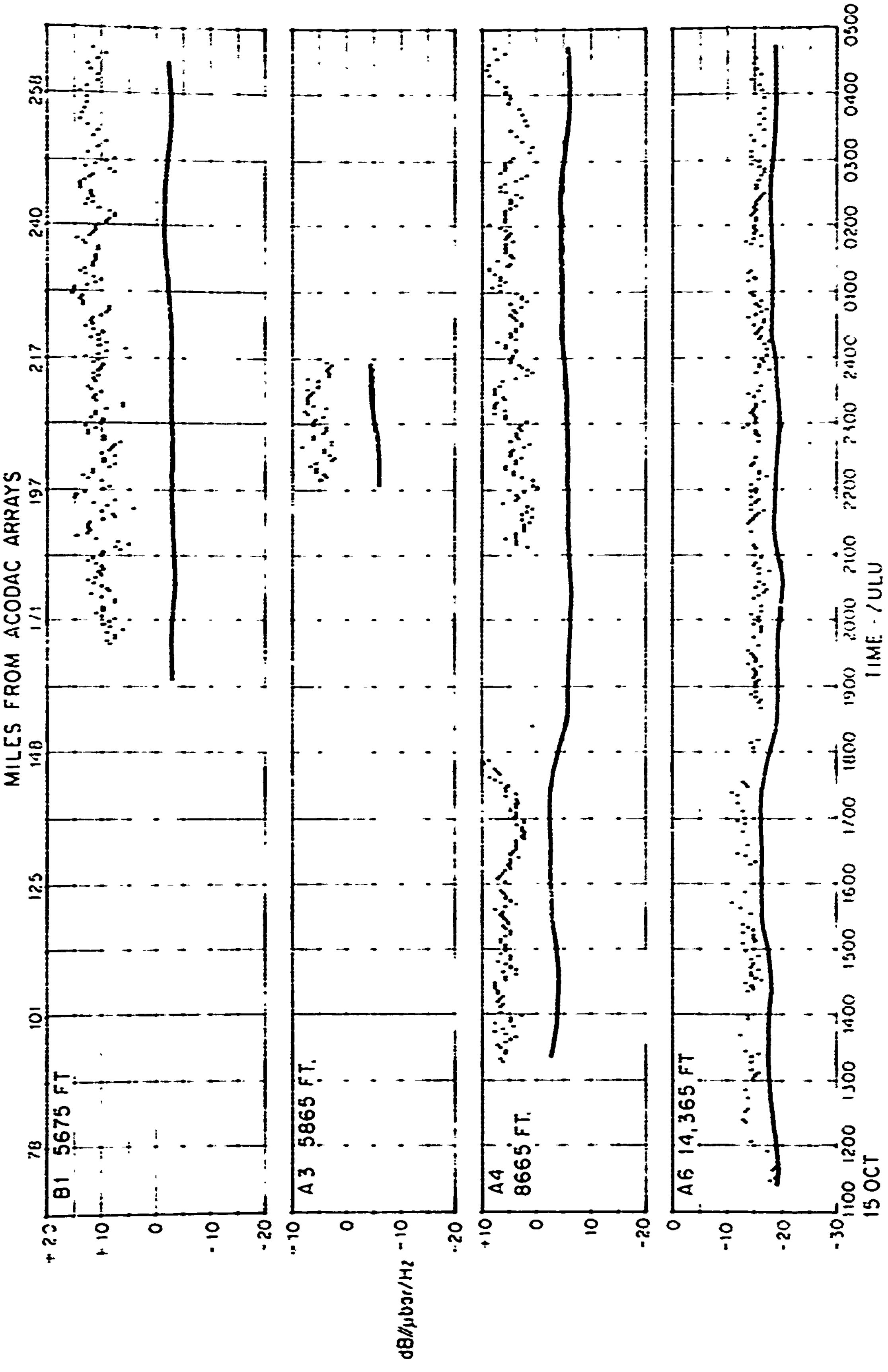


AMBIENT NOISE - ONE HOUR AVERAGES (U)
MEASURED IN 1/3 OCTAVE BAND AT 100Hz
FIGURE 8



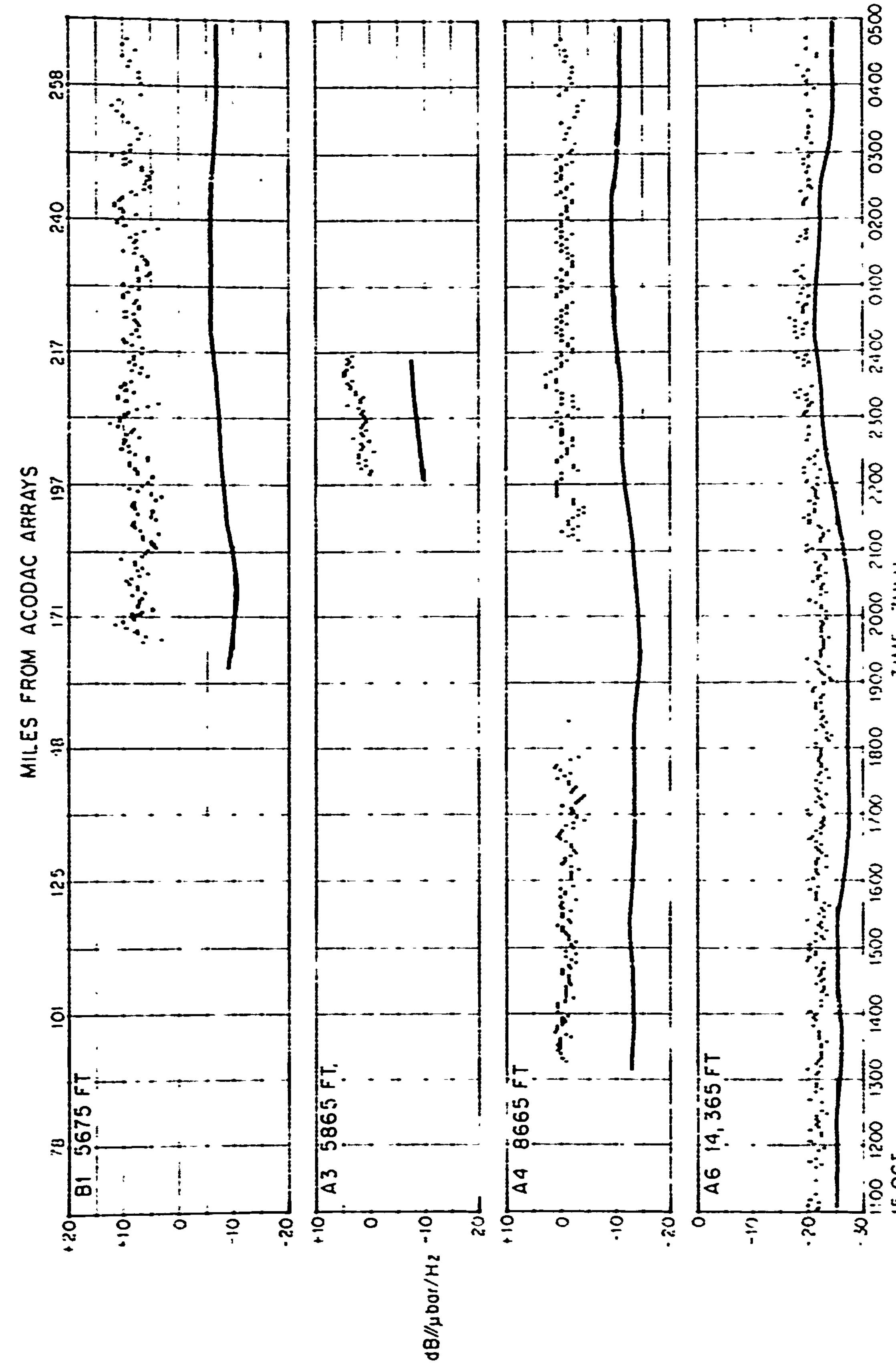
AMBIENT NOISE AVERAGED OVER 15 HALF HOUR INTERVALS DURING A 24 HOUR PERIOD FROM 2000/15-2000/16 (U)

FIGURE 9



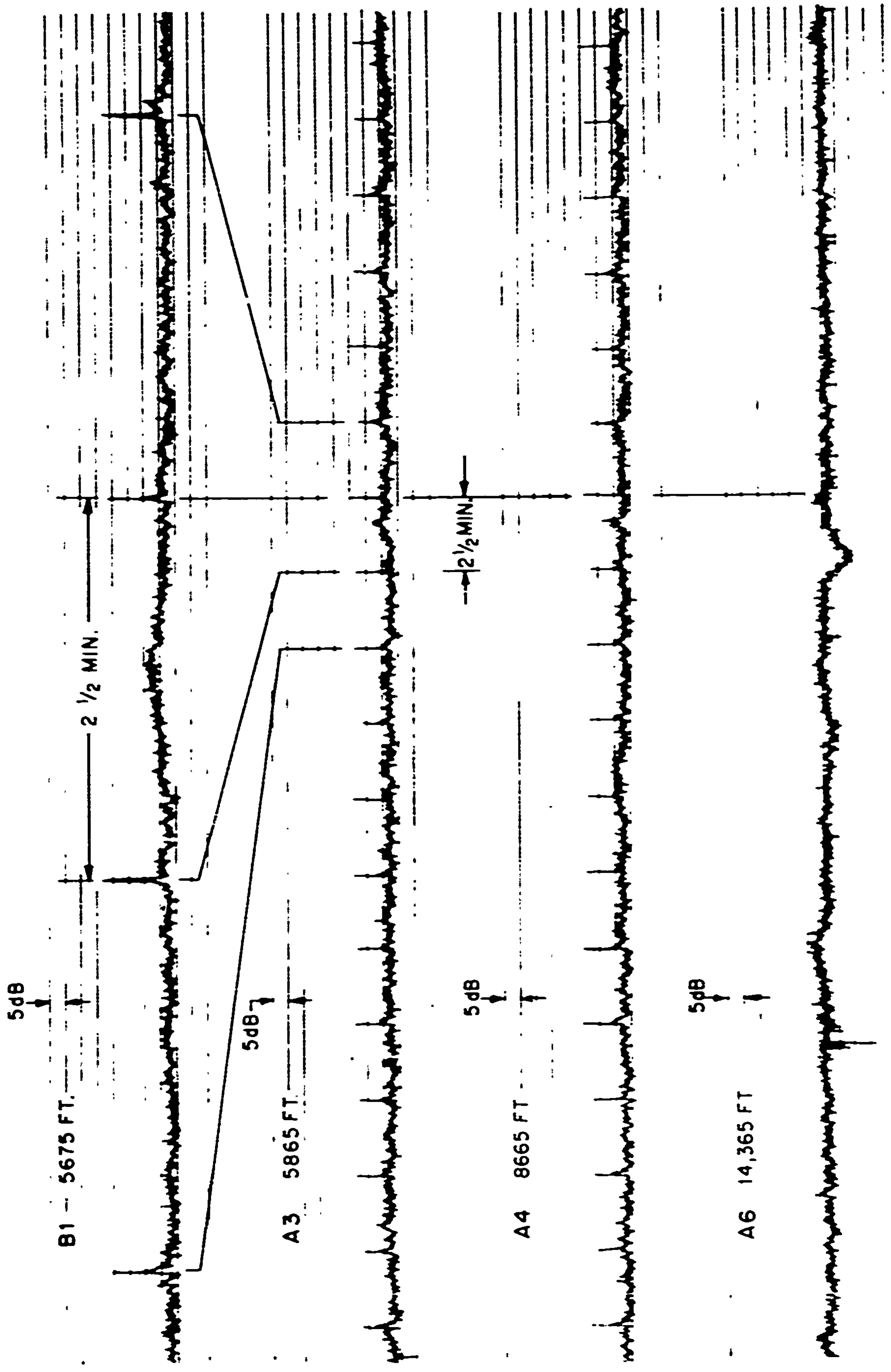
PEAK SHOT SIGNAL AMPLITUDES AND ONE HOUR AVERAGE AMBIENT NOISE LEVELS MEASURED IN 1/3 OCTAVE BAND AT 50Hz (U)

FIGURE 10



PEAK SHOT SIGNAL AMPLITUDES AND ONE HOUR AVERAGE AMBIENT NOISE LEVELS MEASURED IN $^{1}/_{3}$ OCTAVE BAND AT 100Hz (U)

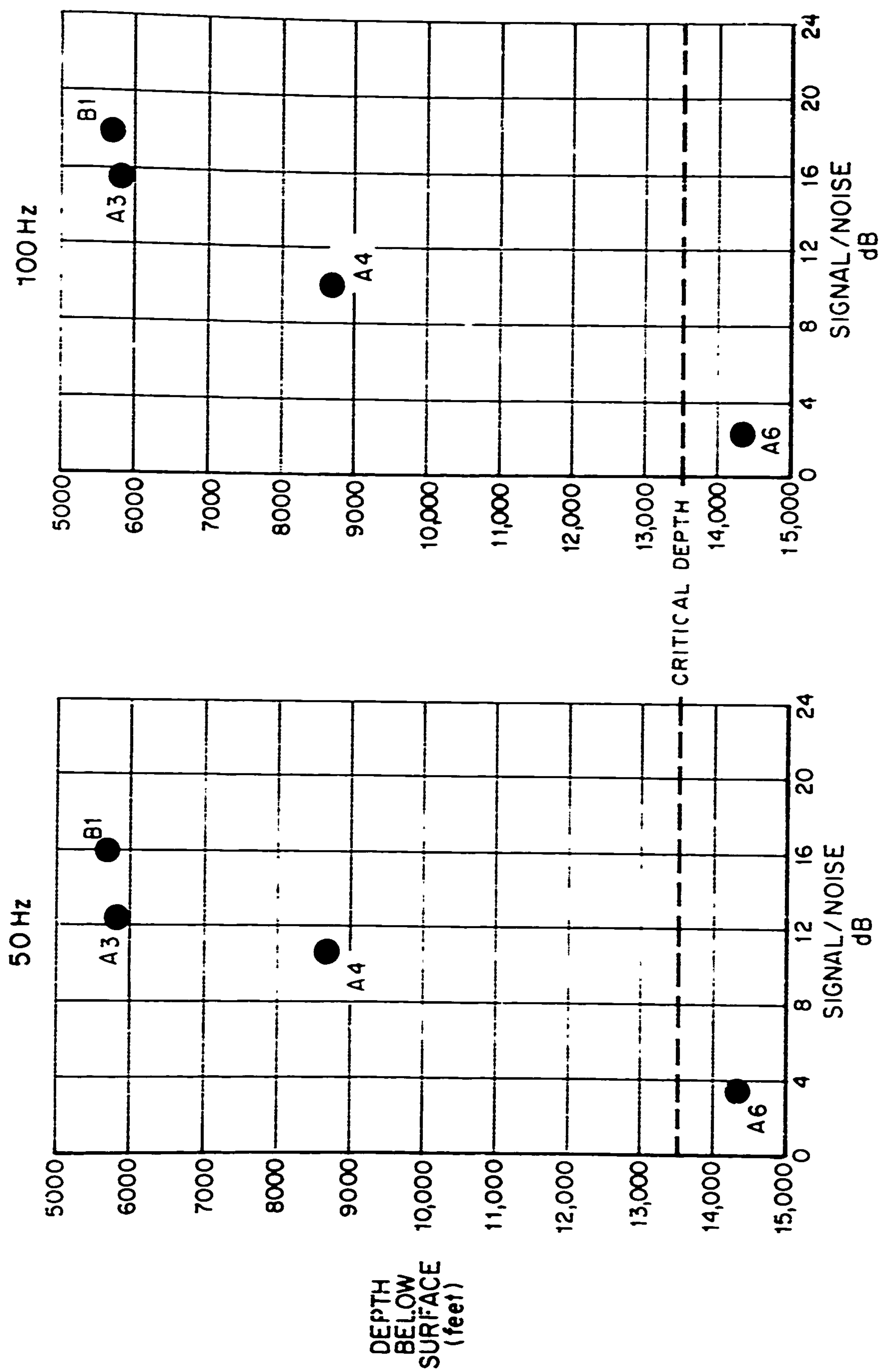
FIGURE 11



NOTE DIFFERENT TIME SCALE FOR B1

RAW SHOT SIGNALS AND NOISE MEASURED IN 1/3 OCTAVE BAND AT 100 Hz (U)

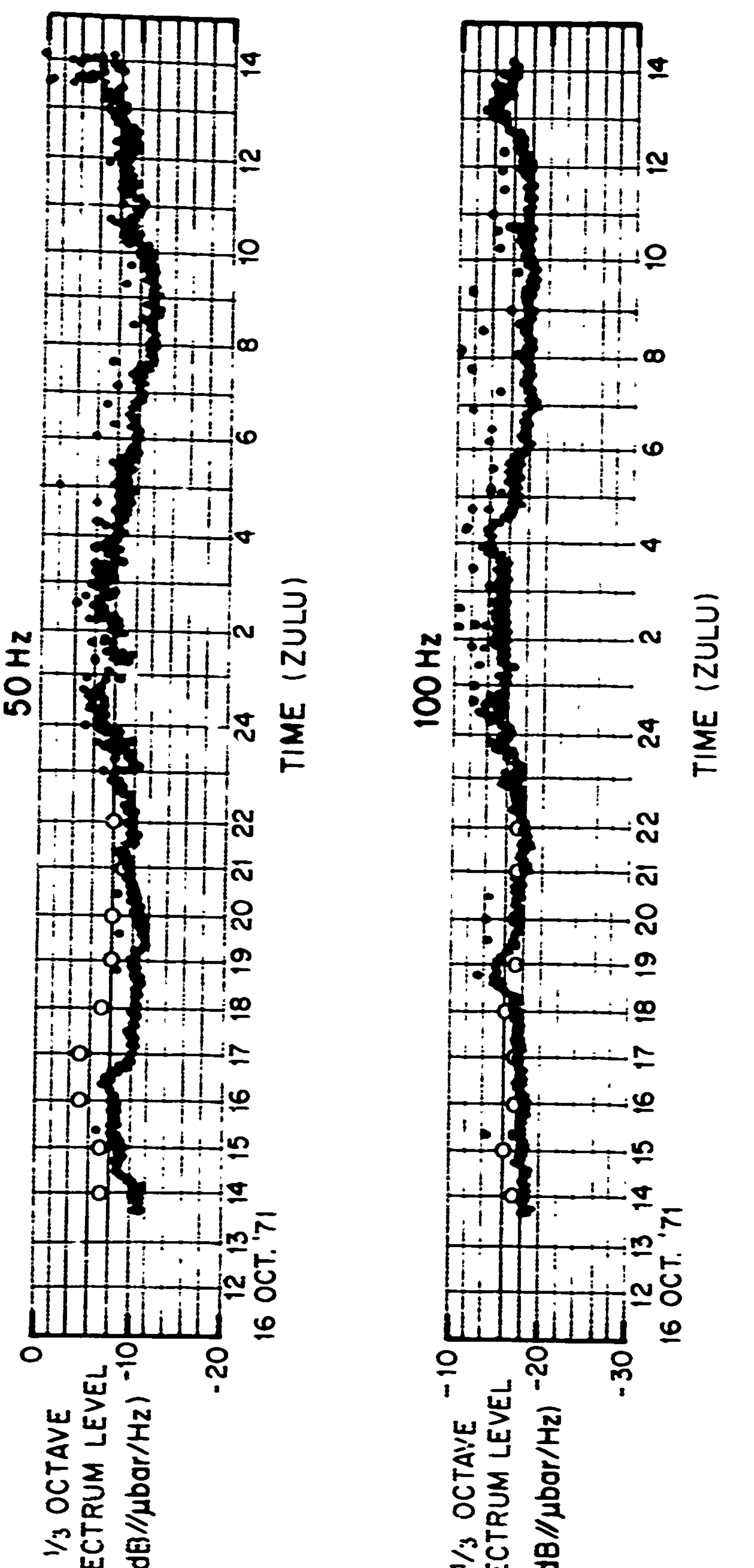
FIGURE 12



PEAK SHOT SIGNAL TO HOURLY AVERAGE AMBIENT NOISE RATIO VS DEPTH (U)

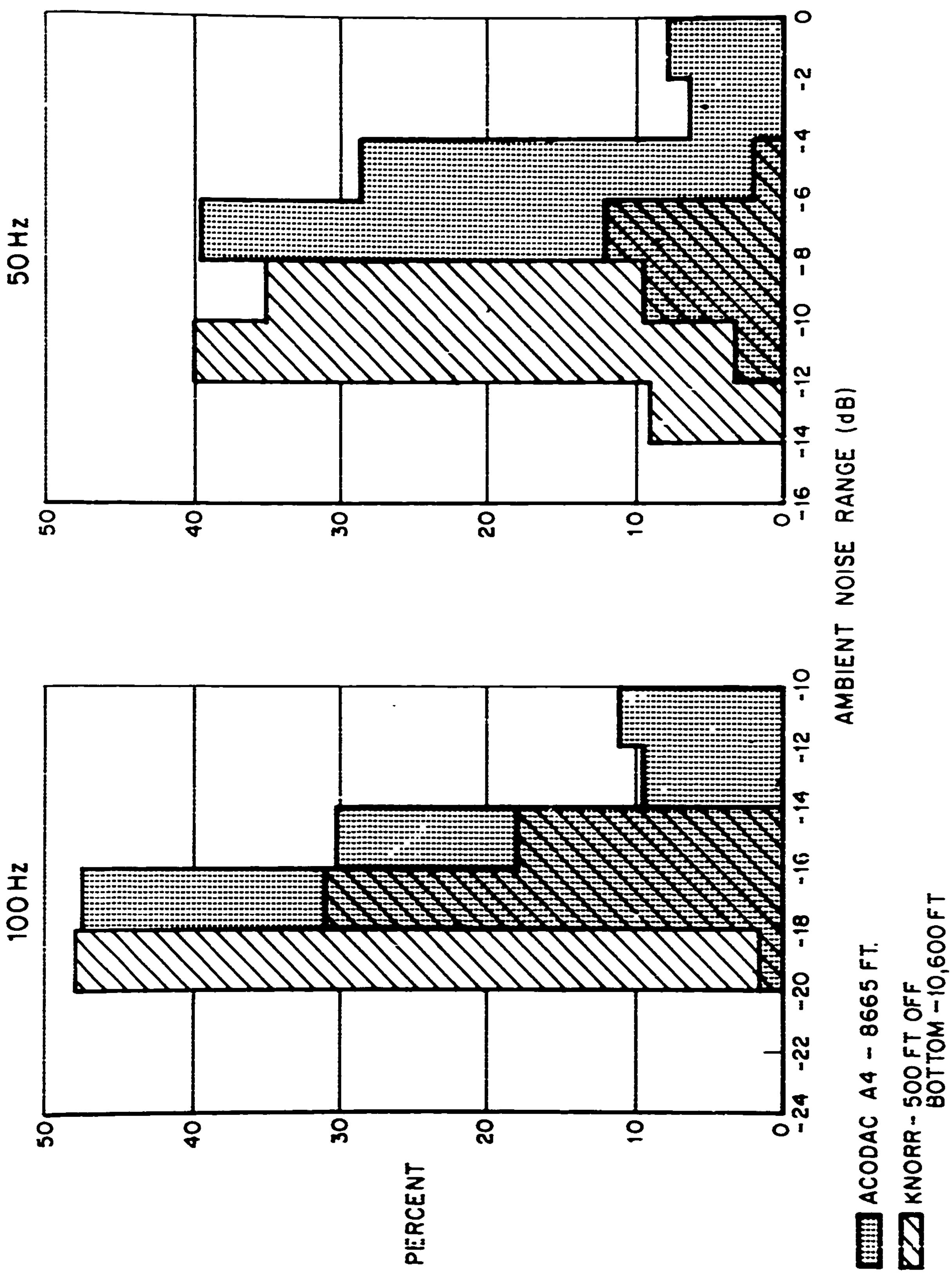
22-2400 Z 15 OCT. '72

FIGURE 13



O ACODAC A4 – 8665 FT. – 1 HOUR AVERAGES
• KNORR – 10,600 FT. – 5 MINUTE AVERAGES

KNORR ACODAC SYNOPTIC COMPARISON (U)
FIGURE 14



COMPARISON OF ACODAC A4 AND KNORR (U)
FIGURE 15

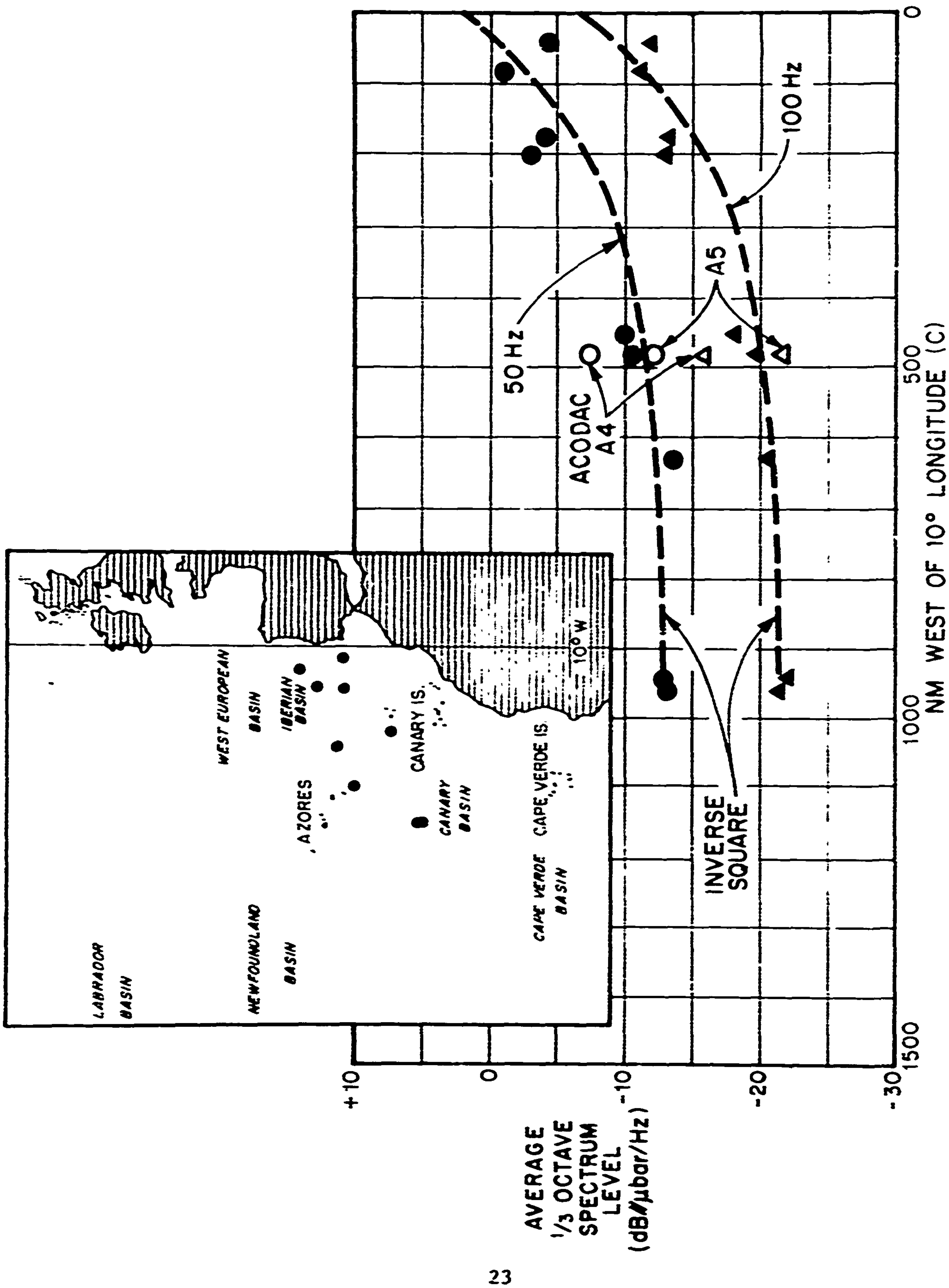

AVERAGE
1/3 OCTAVE
SPECTRUM
LEVEL
(dB/μbar/Hz)
+10
0
-10
-20
-30
0
500
1000
1500
NM WEST OF 10° LONGITUDE (C)
50 Hz
100 Hz
A5
ACODAC
A4
INVERSE
SQUARE
LABRADOR
BASIN
NEWFOUNDLAND
BASIN
WEST EUROPEAN
BASIN
IBERIAN
BASIN
AZORES
CANARY IS.
CANARY
BASIN
CAPE VERDE IS.
CAPE VERDE
BASIN
10° W

FIGURE 16

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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
HLR167; CU-195-69-ONR-266-PHYS	Hardy, W. A.	PROJECT APTERYX: FINAL REPORT (U) (HUDSON LABORATORIES OPERATION 245)	Columbia Univ./ Hudson Labs	690301	NS; ND AD501319	C
MCR002	Unavailable	MEDITERRANEAN SEA ENVIRONMENTAL ATLAS FOR ITASS (U)	Maury Center for Ocean Science	691001	NS; ND AD506976	C
NUSCNL3018	Unavailable	TECHNICAL PLAN FOR IMPLANTMENT OF THE TEST BED ARRAY FOR THE LONG RANGE ACOUSTIC PROPAGATION PROGRAM (LRAPP) (U)	Naval Underwater Systems Center	700810	NS; ND	C
Project469 149429855R700	Balaban, M. M.	LRAPP TEST BED ARRAY CABLE FAILURE ANALYSIS (U)	TRW Systems Group	710730	AD0516710; NS; ND	C
BKDCN667	Bernard, P. G., et al.	TECHNICAL DIAGNOSTIC ANALYSIS OF LRAPP TEST BED PROGRAM FAILURE (U)	B-K Dynamics, Inc.	710802	AD0516656; NS; ND	C
NUSCPUB6002	Unavailable	IOMED EXPERIMENT. PRELIMINARY DATA REPORT (U)	Naval Underwater Systems Center	711206	NS; ND	C
ADL ED 15316; ADL-116-672	Unavailable	SQUARE DEAL EXERCISE PLAN (U)	Arthur D. Little, Inc.	720301	ND	C
ADLR4560372	Sullivan, D. L., et al.	PRELIMINARY ANALYSIS OF ACODAC MEASUREMENTS NEAR MADEIRA ON 13-16 OCTOBER 1971 (U)	Arthur D. Little, Inc.	720331	AD0595812; NS; ND	C
MCR07	Gaul, R. D., et al.	IOMEDEX SYNOPSIS ON ENVIRONMENTAL ACOUSTIC EXERCISE IN THE IONIAN BASIN OF THE MEDITERRANEAN SEA NOVEMBER 1971.	Maury Center for Ocean Science	720401	NS; ND	C
P1243	Unavailable	FINAL REPORT ACOUSTIC TEST ARRAY (U)	Raytheon Co.	720831	AD0522104; NS; ND	C
Unavailable	Unavailable	CHART-BATHYMETRIC-SQUARE DEAL EXERCISE (U)	Naval Oceanographic Office	730601	AU	C
TM SA23-C275-73	Wilcox, J. D.	A DESCRIPTION OF THE LRAPP ATLANTIC TEST BED ARRAY FOR MOTION PREDICTION STUDIES (U)	Naval Underwater Systems Center	731212	ND	C
Unavailable	Unavailable	CHURCH ANCHOR AMBIENT NOISE REPORT (U)	Texas Instruments, Inc.	740501	AU	C
Unavailable	Hoffman, J., et al.	CHURCH ANCHOR CW PROPAGATION LOSS AND SIGNAL EXCESS REPORT(U)	Texas Instruments, Inc.	740701	AU; ND	C
MCR104	Unavailable	MEDITERRANEAN ENVIRONMENTAL ACOUSTIC SUMMARY (U)	Maury Center for Ocean Science	740701	NS; ND	C
OSTP-39	Romain, N. E.	OSTP-39 NER: ANALYSIS OF DATA FROM A FIELD TRIAL OF THE LAMBDA ARRAY (U)	Westinghouse Electric Corp. and Bell Laboratories	740930	ND	C
MC-103	Unavailable	MEDITERRANEAN ENVIRONMENTAL ACOUSTIC DATA CATALOG (U)	Office of Naval Research	750501	ND	C
Unavailable	Unavailable	SQUARE DEAL SUS TRANSMISSION LOSS (U)	Arthur D. Little, Inc.	750725	AU	C

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